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IS THERE MORE THAN ONE SOURCE FOR THE TEMPORAL BINDING FACTOR FOR HUMAN CONSCIOUSNESS?[1]

M. A. PERSINGER

Laurentian University

Summary.—If the emergence of higher order consciousness is produced by transcerebral electromagnetic processes recreated every 20 msec. to 25 msec., then any frequency band in addition to the 40-Hz range could serve as a binding factor for this process. Second order differences or "derivatives," obtained by lagging differences in real time between adjacent frequency integers, indicate that 20 msec. to 25 msec. intervals could be continuously recreated by shifts in frequency within approximately 6.3 and 7.8 Hz. Higher order differences indicate that variations within very narrow band widths between 5 Hz and 6 Hz would generate continuous recreations of 20-msec. to 25-msec. intervals.

Measurements by Llinas and Ribary (1993) have suggested that the temporal substrate for conscious cognition may be recreated every 20 msec. to 25 msec. through re-entrant processes. These occur transcerebrally and result in a 'binding factor' that allows all intracortical electromagnetic fields to interact. This binding factor, which may predominantly involve phase shifting electromagnetic fields that move in a rostral to caudal direction through the cortical manifold, is assumed to be the source of the broad 40-Hz electroencephalographic band (Jeffreys, Traub, & Whittington, 1996) that may be a primary correlate of both the waking state and dreams (Llinas & Ribary, 1993).

If the recreation of this electromagnetic binding factor every approximately 20 msec. to 25 msec. is the critical component to the emergence of consciousness, then any temporal process whose fundamental shift per pulse produces this discrete window may be a candidate for support or production of the electromagnetic correlates of consciousness. To discern fundamental frequencies within which these windows might exist, the duration in msec. of each cycle between 1 Hz and 60 Hz was calculated by dividing 1 by the integers of each frequency, e.g., 1/60, 2/60. First-order differences were calculated by subtracting the duration in msec. of each frequency from the value in msec. of the previous frequency (lag = 1) for the entire range of 60 Hz. Second-order differences were calculated by subtracting these first order differences in msec. from the durations for each previous value (lag = 1) for the entire range of 60 Hz. Third-order differences were calculated by

[1]Please send reprint requests to Dr. M. A. Persinger, Behavioral Neuroscience Laboratory, Department of Psychology, Laurentian University, Sudbury, Ontario, Canada P3E 2C6.

subtracting the second-order differences from the values for each previous value (lag = 1). All values were expressed in msec. and calculated by SPSS programs.

The zero-order values (1/frequency) indicated a wide band of frequencies between 39 Hz and 50 Hz that would support intervals of 20 msec. to 25 msec. If the range of intervals was expanded to include between 15 msec. and 30 msec., the frequency band between 33 Hz and 67 Hz would be included. For the first-order differences, increments between 20 msec. and 25 msec. would occur during shifts between 6.7 Hz and 7.2 Hz, while the range between 15 msec. and 30 msec. would include the narrow band between about 6.3 Hz and 7.8 Hz. For the second- and third-order differences, increments between 20 msec. and 25 msec. would occur around 5.8 Hz to 5.9 Hz. For the increments of 15 to 30 msec., the supporting fundamental frequencies would be between 5.1 Hz and 6.1 Hz for the second-order, and within an 0.5 Hz band around 6 Hz for the third-order differences.

If one assumes Edelman's (1989) hypothesis that re-entrant processes within large intracortical fields are the bases for higher-order consciousness, then the wide 40 Hz band may represent only one dimension within which consciousness can emerge and exist. The temporal increments produced during shifts of transcerebral frequencies between 6 Hz and 7 Hz for the narrower band (for 20 msec. to 25 msec.) and between approximately 6.5 Hz and 8 Hz for the wider band (10 msec. to 30 msec.) would also qualify as potential binding factors for consciousness. The latter frequency range is within the classic band of theta activity which has been associated with states of consciousness for creativity, hypnagogic states (De Pascalis, Ray, Tranquillo, & D'Amico, 1998), and access of information from the environment through mechanisms not known to date.

The centroid for the peak frequency for the fundamental Schumann resonance (Campbell, 1967), which is generated within and throughout the earth's atmosphere, lithosphere, and the ionosphere, is 7.8 Hz. Although the possibility of spurious association must remain foremost at this time, the occurrence of narrow variations in frequency around 7.8 Hz within the earth's spherical wave guide suggests that interactions might occur between human brains and the geophysical environment (Persinger, 1983). The possibility of emergent properties from large collections of human brains within states of consciousness correlated with this frequency and the geophysical environment might be considered.

The clustering of the approximately 20-msec. intervals, based upon the differences in time between first-order and second-order subtractions, for small shifts in frequency between 5 Hz and 6 Hz suggest that substrates for consciousness might exist in a very narrow band of phase shifts that occur

TABLE 1

DURATIONS (IN MSEC.) OF DIFFERENCES FOR D1 (LAG 1 OF MSEC. MINUS MSEC.), D2 (LAG OF D1 MINUS D1), D3 (LAG OF D2 MINUS D2), AND D4 (LAG OF D3 MINUS D3) AS A FUNCTION OF FUNDAMENTAL FREQUENCIES (Hz) IN MSEC.

Hz	msec.	d1	d2	d3	d4
.5	2000.00	500.00	333.33	500.00	2000.00
.6	1666.67	333.33	166.67	166.67	333.33
.7	1428.57	238.10	95.24	71.43	95.24
.8	1250.00	178.57	59.52	35.71	35.71
.9	1111.11	138.89	39.68	19.84	15.87
1.0	1000.00	111.11	27.78	11.90	7.94
2.0	500.00	500.00	388.89	361.11	349.21
3.0	333.33	166.67	333.33	55.56	305.56
4.0	250.00	83.33	83.33	250.00	194.44
5.0	200.00	50.00	33.33	50.00	200.00
6.0	166.67	33.33	16.67	16.67	33.33
7.0	142.86	23.81	9.52	7.14	9.52
8.0	125.00	17.86	5.95	3.57	3.57
9.0	111.11	13.89	3.97	1.98	1.59
10.0	100.00	11.11	2.78	1.19	.79
11.0	90.91	9.09	2.02	.76	.43
12.0	83.33	7.58	1.52	.51	.25
13.0	76.92	6.41	1.17	.35	.16
14.0	71.43	5.49	.92	.25	.10
15.0	66.67	4.76	.73	.18	.07
16.0	62.50	4.17	.60	.14	.05
17.0	58.82	3.68	.49	.11	.03
18.0	55.56	3.27	.41	.08	.02
19.0	52.63	2.92	.34	.06	.02
20.0	50.00	2.63	.29	.05	.01
21.0	47.62	2.38	.25	.04	.01
22.0	45.45	2.16	.22	.03	.01
23.0	43.48	1.98	.19	.03	.01
24.0	41.67	1.81	.16	.02	.00
25.0	40.00	1.67	.14	.02	.00
26.0	38.46	1.54	.13	.02	.00
27.0	37.04	1.42	.11	.01	.00
28.0	35.71	1.32	.10	.01	.00
29.0	34.48	1.23	.09	.01	.00
30.0	33.33	1.15	.08	.01	.00
31.0	32.26	1.08	.07	.01	.00
32.0	31.25	1.01	.07	.01	.00
33.0	30.30	.95	.06	.01	.00
34.0	29.41	.89	.06	.01	.00
35.0	28.57	.84	.05	.00	.00
36.0	27.78	.79	.05	.00	.00
37.0	27.03	.75	.04	.00	.00
38.0	26.32	.71	.04	.00	.00

(continued on next page)

TABLE 1 (CONT'D)
DURATIONS (IN MSEC.) OF DIFFERENCES FOR D1 (LAG 1 OF MSEC. MINUS MSEC.), D2 (LAG OF D1 MINUS D1), D3 (LAG OF D2 MINUS D2), AND D4 (LAG OF D3 MINUS D3) AS A FUNCTION OF FUNDAMENTAL FREQUENCIES (HZ) IN MSEC.

Hz	msec.	d1	d2	d3	d4
39.0	25.64	.67	.04	.00	.00
40.0	25.00	.64	.03	.00	.00
41.0	24.39	.61	.03	.00	.00
42.0	23.81	.58	.03	.00	.00
43.0	23.26	.55	.03	.00	.00
44.0	22.73	.53	.03	.00	.00
45.0	22.22	.51	.02	.00	.00
46.0	21.74	.48	.02	.00	.00
47.0	21.28	.46	.02	.00	.00
48.0	20.83	.44	.02	.00	.00
49.0	20.41	.43	.02	.00	.00
50.0	20.00	.41	.02	.00	.00
51.0	19.61	.39	.02	.00	.00
52.0	19.23	.38	.02	.00	.00
53.0	18.87	.36	.01	.00	.00
54.0	18.52	.35	.01	.00	.00
55.0	18.18	.34	.01	.00	.00
56.0	17.86	.32	.01	.00	.00
57.0	17.54	.31	.01	.00	.00
58.0	17.24	.30	.01	.00	.00
59.0	16.95	.29	.01	.00	.00
60.0	16.67	.28	.01	.00	.00
61.0	16.39	.27	.01	.00	.00
62.0	16.13	.26	.01	.00	.00

within a fraction of 1 Hz. Unless special electroencephalographic measurements with significant resolution were obtained, this variation would be obscured by the limitations of instrumentation. The continuation of n^{th}-order extrapolations defines narrower and narrower windows of frequency shifts or phase alterations around 6 Hz as possible mediators of consciousness.

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